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"SFERICS" AND THE LIGHTNING DISCHARGE

By R. H. GOLDE, Ph.D.

In a Friday evening discourse before the Royal Institution on May 18, 1860, Sir William Thompson,[1*] as he then was, expressed the conviction that "electric indications" such as those obtained with a water-dropping collector connected to an electrometer "will be found important additions to our means for prognosticating the weather". In fact, from a pronounced movement of the electrometer during the discourse the lecturer predicted that the preceding dull rainy weather would give way to fairer conditions, an observation which was strikingly confirmed by the cessation of the rain and the onset of fair weather conditions which lasted for several days after!

Unfortunately Lord Kelvin's hope "to see the atmospheric electrometer generally adopted as a useful and convenient weather-glass" was not fulfilled. However, in his quest for improved weather forecasting the meteorologist has been able to make good use, in fact the only practical use so far, of another electrical manifestation, namely the lightning discharge. In an article[2] which appeared in this Magazine the "sferics" organization of the Meteorological Office has been described, and it has been stated that the atmospheric disturbances on which this service is based are caused by lightning discharges at distances of hundreds or thousands of miles from the point of recording.

The present article discusses those characteristics of the lightning discharge which may assist in an understanding of the development of atmospherics.

Initiation of the lightning discharge.—Our knowledge of the thermodynamical processes underlying the development of cumulus clouds has been greatly extended by a recent comprehensive investigation carried out by the United States Air Force and reported by Byers[3]. From these investigations a cumulonimbus cloud is now known to consist of a number of individual cells each of which has a regular life cycle with its corresponding state of electrification.

In the present context it is of special interest to find that the lower region of an active cell contains water drops while the upper part is filled with ice crystals, the whole cell being subject to violent winds both upwards and downwards. This picture of a thundercloud confirms Simpson's[4] earlier conception, derived from balloon measurements, which led to the picture of a typical thundercloud reproduced in Fig. 1. This shows a bipolar charge distribution with an upper positive charge and a lower negative charge,

* These numbers refer to the list of references on p. 285.

the line of charge separation coinciding roughly with the 0°C. isotherm. The concentrated region of positive charge near the lower edge of the cloud, although frequently present, may be absent.

While this charge distribution can be regarded as fairly well established the mechanism underlying the charging process is still a matter of controversy. All that can be claimed with some degree of certainty is the observation that the charging process is bound up with the development of ice crystals, and that the rate of charge generation is so rapid during the mature stage of the thunderstorm cell as to re-establish within a matter of seconds the large electric charges which may be removed as the result of a lightning flash.

A potential difference—or what is basically the same, a charge separation —between two metallic electrodes in the laboratory is known to produce an electric discharge in the form of a spark if the electric field strength in the space between the electrodes reaches a value of about 30,000 v /cm. If the two electrodes are widely separated and if their shapes are such as to produce

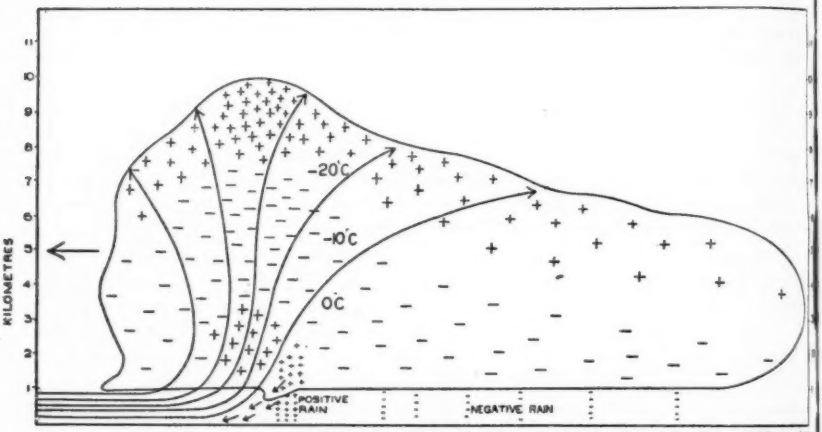

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FIG. 1—DIAGRAM OF CONDITIONS IN A THUNDERSTORM

a strongly non-uniform field distribution between them with a strong field concentration at the surface of at least one of them, breakdown may occur at an average field strength of some 3,000 v. /cm.

The laboratory case differs from the conditions in a charged thundercloud in more than one respect. Thus the cloud is a poor conductor, the atmosphere in a cloud is more or less saturated with water drops of varying size, and the atmospheric pressure is reduced below that at the earth's surface. It has been shown by Macky[5] that an electric discharge may be started in an atmosphere containing water drops at a field strength of about 10,000 v./cm., but even this value exceeds the average field measured in the region below the thundercloud by a factor of about 30 to 100.

The possibility of the propagation of an electric discharge in such weak electric fields was first suggested by Toepler[6, 7]. In support of this suggestion he performed a simple experiment which is worth recalling even if it is not exactly analogous to the lightning discharge. Between two glass plates A and B (see Fig. 2) two tin foils are placed such that a central strip between

the glass plates is left free. A potential is applied across the two tin foils thus producing a high electric field strength in the centre region of the outer glass surface. If a water drop is now placed in a position D an electric discharge is initiated both in an upward and downward direction, and with increasing potential difference between the tin foils the discharges grow right up to the edges of the plate, i.e. far into a region which, prior to the occurrence of the discharge itself, was practically free from any electric field. Such a discharge can be called " self-propagating ".

In a similar manner a lightning discharge may be assumed to be initiated when a local field strength of about 10,000 v./cm. is reached at the surface of a single water drop or ice crystal, or an accumulation of such drops or crystals, and when the average field strength throughout the surrounding atmosphere is sufficient to sustain a self-propagating discharge. According to

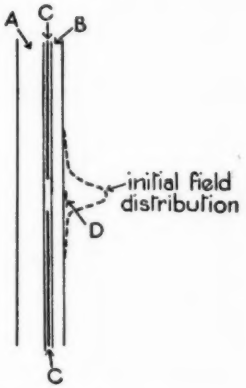

FIG. 2—ELECTRIC SURFACE DISCHARGE AS ANALOGY TO FORMATION OF LIGHTNING DISCHARGE

(after Toepler)

A, B Glass plates
C Tin foil
D Water drop

Bruce[8] the field strength required for such a lightning discharge is of the order of 200–300 v./cm., a value which agrees with field observations, the only lower limit of this gradient being that necessary to maintain an arc which, under the prevailing conditions, requires a gradient of about 10 v./cm.

Applying this mechanism to Fig. 1, three distinct types of lightning discharge are seen to be feasible : a discharge from the bottom of the cloud to earth, a discharge between the positive and negative charges in the same or neighbouring cloud cells, or a discharge from the upper cloud charge into the upper atmosphere. All these types are known to occur although the last-named variety is difficult to observe. A photograph showing cloud-earth and cloud-cloud discharges and a further discharge which may possibly belong to the last-named category is shown in the photograph facing p. 284.

Mechanism of the lightning discharge.—From the historical point of view it is interesting to note that the first ideas on the propagation of the lightning discharge were derived from observations of the laboratory spark.

By using a rapidly rotating camera Walter [9,10] obtained the photograph facing p. 285. This shows that a spark between two metal electrodes proceeds from both electrodes in several discrete steps with considerable time intervals between the individual steps, each of which is longer than the preceding one. With greatly improved means of recording, this development of the long laboratory spark discharge was later confirmed and elaborated by Allibone and Meek[11].

A more detailed examination of the lightning discharge had to wait for the development of the rotating camera, introduced by Boys, which permits a resolution of time down to about 1 microsecond, and which, in addition, gives a clear indication of the direction of propagation of the discharge phenomenon. From the investigations of Schonland[12] and his collaborators in South Africa with the Boys camera a normal stroke to earth is known to proceed from the cloud in a sequence of steps of almost uniform length and with similarly constant time intervals between successive steps. This development of the leader stroke, as it was termed by Schonland, is shown diagrammatically in

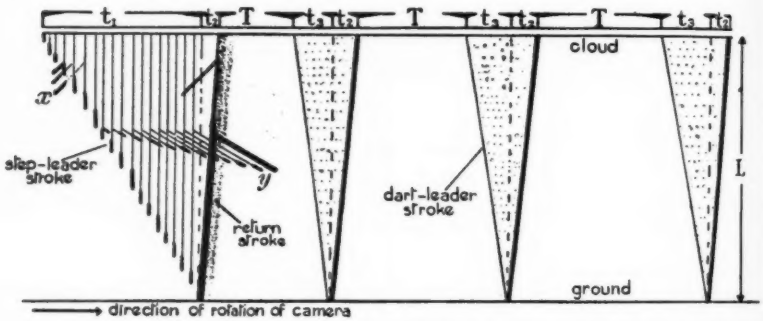

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FIG. 3—DIAGRAMMATIC REPRESENTATION OF A MULTIPLE LIGHTNING STROKE TO EARTH

Average values : $t_1 = 0{\cdot}01$ sec. ; $t_2 = 0{\cdot}00004$ sec. ; $t_3 = 0{\cdot}001$ sec. ; $T = 0{\cdot}03$ sec. ; $L = 2$ Km.

Fig. 3. On reaching the earth or a short upward streamer discharge emanating from the earth[13], the faintly luminous leader stroke is followed by the brilliant return stroke which travels upwards towards the cloud with a velocity which, initially, may reach half the velocity of light, but which decreases as the return stroke reaches greater heights above the earth.

In many cases this process comprises the whole lightning discharge. Fifty per cent. of the discharges photographed produce, however, subsequent strokes which normally follow in every detail the course taken by the first stroke, apart from the absence of branching in subsequent component strokes. Furthermore, these subsequent strokes start with a leader which covers the distance from cloud to earth in one "dart", which is then followed by a return stroke of the same type as that in the first stroke. This process may be repeated several times and up to 42 components have been reported. From a statistical examination[14] of the quantitative information available lightning strokes are known to show the same mechanism all over the world, although it should be noted that our more detailed knowledge is at present confined to negative lightning flashes ; the positive flashes which are known to occur in temperate regions are almost completely absent in South Africa.

An exception to this picture has been observed at the Empire State Building in New York where McEachron[15] found the normal lightning process to be initially reversed. More often than not, the leader stroke starts from the top of the building developing upwards towards the cloud in the same general manner as does the normal leader towards earth. However, on reaching the cloud the leader is not followed by a return stroke, but by a much weaker continuing discharge. This type of discharge is of particular interest because there are reasons to believe that it also describes the typical cloud-cloud discharge which cannot be readily photographed but which appears to consist of a stepped leader stroke without subsequent return stroke. If in the case of the Empire State Building the first stroke is followed by further strokes, these revert to the normal mechanism with downward dart leaders and subsequent upward return strokes.

For an explanation of the stepped leader process Bruce[8] makes use of a phenomenon which had already been suggested by Toepler[7] who had investigated it extensively in the electrodeless spark discharge along an insulating surface. This starts as a diffused brush discharge which suddenly changes into a concentrated arc discharge when a given current value is exceeded. As an arc discharge is governed by a negative current/voltage characteristic the leader discharge progresses, on this theory, towards earth in the form of a streamer or brush discharge until transition to the arc state occurs, a process which is repeated at regular time intervals as the discharge channel lengthens.

An alternative theory has been advanced by Schonland and extended by Loeb and Meek[16]. According to this conception the degree of ionization in a given length of channel decreases due to recombination and the resulting field strength increases until breakdown occurs, thus initiating a further step which, in turn, produces further ionization in the step streamer. This theory, however, has been strongly criticized[8].

Radiation produced by the lightning discharge.—In addition to the photographic evidence mentioned so far, equally valuable information on the lightning discharge has been deduced from the electric field changes produced by a lightning flash. Assuming a point charge q at a height H above a conducting plane, the electric field intensity at a horizontal distance y from the projection of the point charge on the plane is

$$e = \frac{2qH}{(H^2 + y^2)^{3/2}} = \frac{M}{r^{3/2}}$$

where M is called the electric moment of the charge and r is the distance between the charge and the point of observation. If the charge q is suddenly lowered to a height h above the plane the resulting field change at the earth's surface is

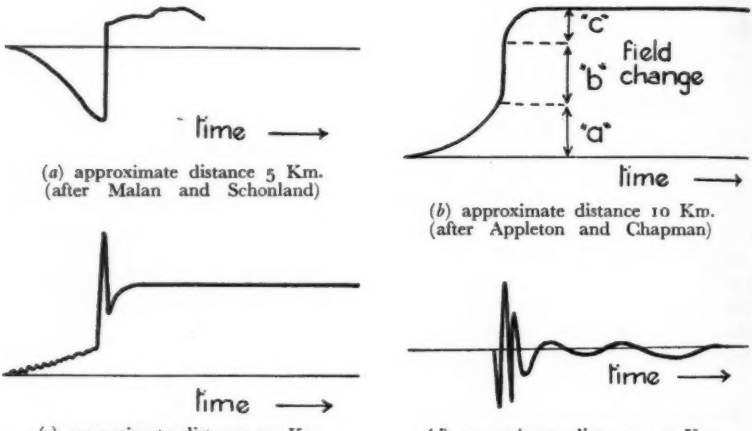
$$E = 2q \left[\frac{H}{(H^2 + y^2)^{3/2}} - \frac{h}{(h^2 + y^2)^{3/2}} \right]$$

From oscillographic records[17, 18] of the field changes produced by a lightning flash information can be obtained on the movement of electric charges during the development of the lightning discharge.

From such evidence the lightning leader stroke is found to be accompanied by a lowering of some of the electric charge stored in the thundercloud, i.e. in the case of a discharge from the negative charge at the bottom region of

the cloud it lowers negative charge into the atmosphere below the cloud. By electrostatic induction the corresponding amount of positive charge collects in the earth underneath the down-coming leader stroke. When the leader contacts earth a violent neutralization results between these two charges of opposite polarity, and this leads to the negative charge in the leader stroke being completely discharged into the earth. Frequently, although not invariably, this period is followed by a further gradual lowering of negative charge from the cloud along the highly ionized lightning path.

The correlation of these three stages with the corresponding field changes, i.e. the gradual " a " field change with the slow leader process, the rapid " b " change with the violent return-stroke process, and the slow " c " field change with the gradual removal of some of the remaining charge in the



(*a*) approximate distance 5 Km. (after Malan and Schonland)

(*b*) approximate distance 10 Km. (after Appleton and Chapman)

(*c*) approximate distance 50 Km. (after Appleton and Chapman)

(*d*) approximate distance 400 Km. (after Appleton and Chapman)

FIG. 4—ELECTRIC FIELD CHANGES DUE TO A LIGHTNING STROKE AT DIFFERENT DISTANCES
(not to scale)

cloud was first suggested by Appleton and Chapman[17] and later convincingly established by Schonland[18]. Typical records obtained[19] at two different distances between observer and lightning stroke are shown in Figs. 4(*a*) and 4(*b*).

In order to describe the total field change caused by a lightning stroke at any distance the above expression for the electrostatic field change has to be replaced by

$$e = \frac{M}{r^3} + \frac{1}{cr^2} \times \frac{dM}{dt} + \frac{1}{c^2 r} \times \frac{d^2M}{dt^2}$$

in which c is the velocity of light and in which the second and third terms represent the induction and the radiation field changes respectively. As these last two terms are the first and second differentials of the electric moment M, the time variation of which is best indicated in Fig. 4(*b*), the induction and radiation terms may be expected to produce oscillatory field changes and these are in fact observed[20–23] at great distances (see Figs. 4(*c*) and 4(*d*))

where the radiation term becomes increasingly predominant over the electrostatic term.

Fig. 4 permits some interesting conclusions to be drawn on the movement of charges during the lightning process. Thus the " a " field change shows a smooth shape at short distances from the lightning stroke (Fig. 4(*a*)) but superimposed oscillations indicative of a radiation field at greater distances (Fig. 4(*c*)). As these latter can be shown to be associated with the fast discrete steps in the first leader stroke the current involved in the step process must be small compared with that of the return stroke. In fact the smooth field change recorded at close distances affords strong support for Schonland's suggestion that the steps in the leader stroke are superimposed on a continuously moving " pilot leader " which is too faint to be photographed. Such a pilot discharge had already been suggested by Walter to precede the stepped streamer formation of a long spark such as is illustrated in the photograph facing p. 285.

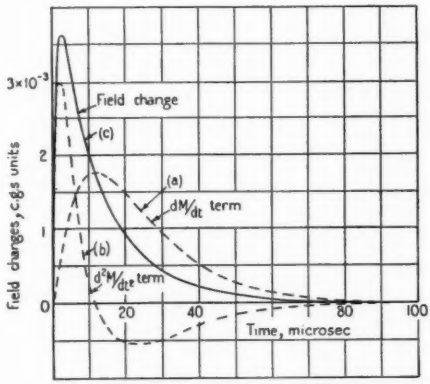


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FIG. 5—CALCULATED INDUCTION AND RADIATION FIELD CHANGES DUE TO A LIGHTNING STROKE AT A DISTANCE OF 3 KM.

The absence of radiation field changes in the " c " portion indicates that a lightning flash to earth is not normally accompanied by any other type of rapid discharge in some other part of the cloud. This observation is of importance because it has been suggested that the visible part of the lightning discharge to earth is, of necessity, linked with a simultaneous upward discharge from the cloud centre tapped towards the upper oppositely charged region of the cloud. Whether the upper positive charge of a bipolar cloud may, as the result of a stroke to earth, be discharged in a continuous type of discharge towards the upper atmosphere remains at present a conjecture.

Turning now to the " b " field change, this is seen from Fig. 4 to give rise to a strong oscillatory radiation which becomes increasingly predominant with increasing distance from the lightning stroke. The effective short circuit between the negative charge in the leader channel and the bound positive charge in the ground below initiates, as already mentioned, an intense process of recombination of the two charges, and this results in a current pulse of high amplitude flowing upwards along the lightning channel. This current pulse

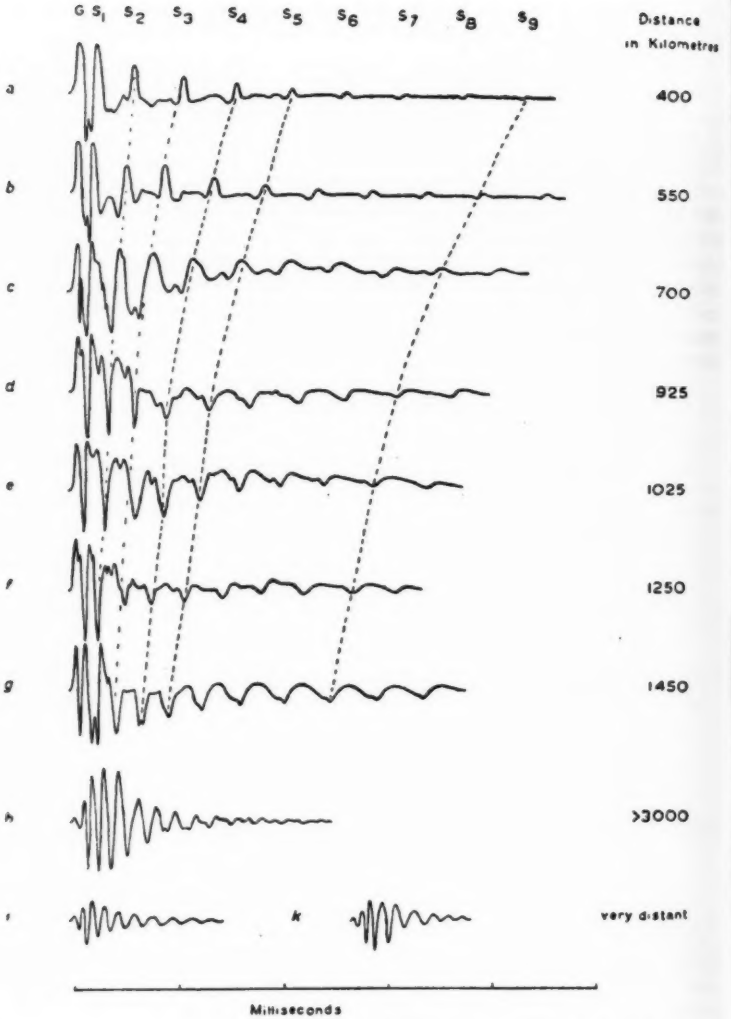

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FIG. 6—ATMOSPHERIC WAVE FORMS AT DIFFERENT DISTANCES FROM A LIGHTNING STROKE

may reach a value up to 160,000 amp. with an average value of about 20,000 amp., and has a double-exponential wave shape which rises to its peak in about 5 microseconds, and falls to a small value in about 100 microseconds. This shape can be expressed by

$$i_L = i_{max} (e^{-at} - e^{-bt})$$

where $a = 4{\cdot}4 \times 10^4$ and $b = 4{\cdot}6 \times 10^5$.

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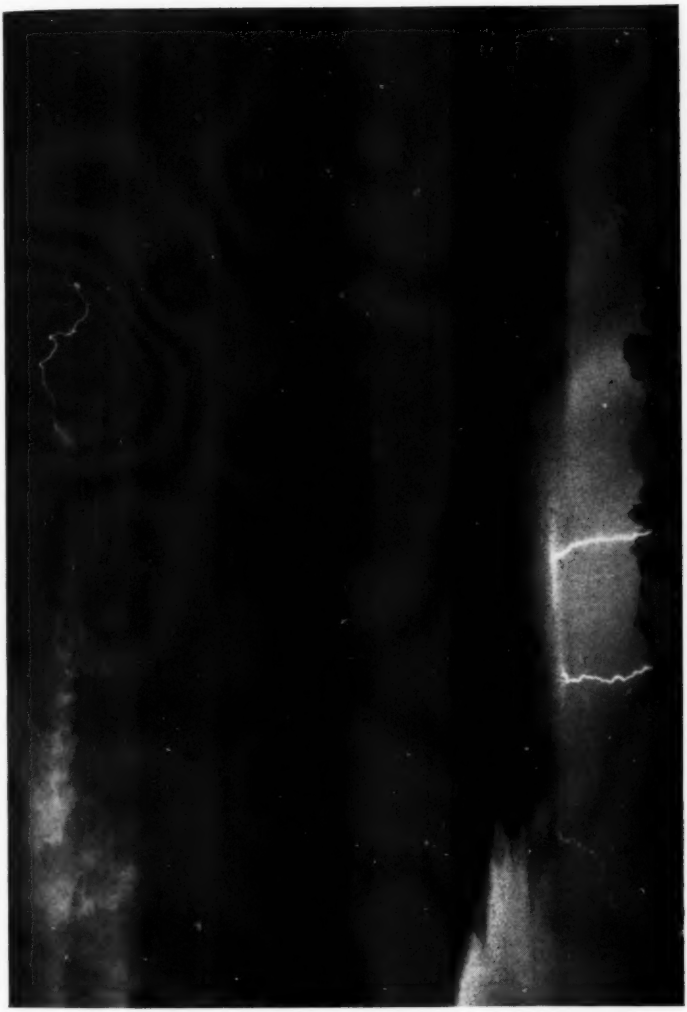
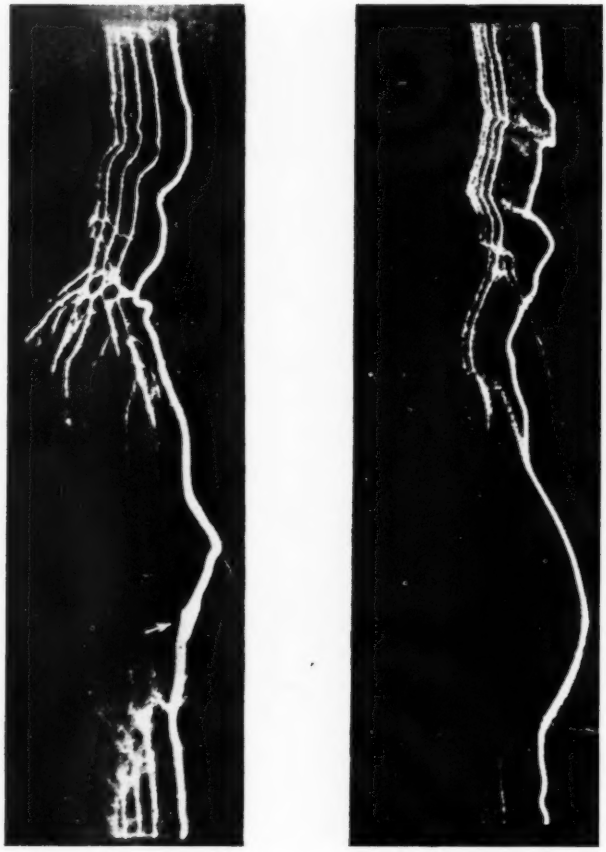


LIGHTNING PHOTOGRAPH AT SPRINGSURE, QUEENSLAND
(See p. 279)



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PHOTOGRAPH OF LABORATORY SPARK (8 CM. LONG)
TAKEN WITH A ROTATING CAMERA

(See p. 280).

From observations with the Boys camera the velocity of the return stroke is found to be described by the expression

$$v = v_0 e^{-\gamma t}$$

where the initial velocity is $v = 8 \times 10^9$ cm./sec. and $\gamma = 3 \times 10^4$. The velocity v is measured in centimetres per second if t is given in seconds.

If the return stroke current is now visualized as a current flowing in a conductor of progressively increasing length, and at any instant of constant amplitude along the appropriate length of channel the inductive field change can be seen[14] to be

$$E_m = \frac{2}{cr^2} \frac{i_L v_0}{\gamma} (e^{-at} - e^{-bt}) \ (1 - e^{-\gamma t})$$

In this way the induction and radiation terms of the field change can be evaluated from the known characteristics of the lightning current. The result of a calculation of the field change is shown in Fig. 5 from which the radiation field at a distance of 3 Km. is found to produce a single oscillation of an equivalent duration of several tens of microseconds. It was first suggested by Laby[24] that the atmospheric wave resulting from such a pulse should consist of a ground or direct pulse followed by a series of discrete reflections of this pulse from a conducting layer in the ionosphere. A detailed investigation of this phenomenon by Schonland and collaborators[25] in which up to 30 such reflections were recorded is reproduced in Fig. 6 in which the gradual merging of the ground and reflected pulses into an oscillatory wave pattern is clearly shown. These measurements proved in fact so accurate as to provide valuable information on the height of the reflecting layer and its variation with time.

As compared with the foregoing strong radiation fields produced by a lightning stroke to earth, the rapid field changes produced by a lightning flash within a thundercloud are confined to the much weaker effects of the step-leader stroke by which such a discharge is initiated.

It is thus established that the oscillatory wave pattern which gives rise to the atmospheric disturbances described as "sferics" is the result of the intense return stroke of a lightning discharge to earth and that all thunderstorms within about 4,000 miles of the observing station are potential sources of these atmospheric disturbances.

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CENTENARY OF MESSRS. NEGRETTI & ZAMBRA

1850–1950

By P. N. SKELTON

The celebration this year of the Centenary of one of the most famous firms of meteorological instrument makers, Messrs. Negretti & Zambra, is an occasion for looking back on their history, and, indeed, on the beginning of meteorological instrument making on an industrial scale in this country.

The firm of Negretti & Zambra was founded by Henry Negretti and Joseph Warren Zambra on April 24, 1850 at 11 Hatton Garden, London.

Henry Negretti, born on November 13, 1818, at Como, Italy, was the son of Paolo Negretti who is reputed to have owned and driven a service of carriage vehicles over the St. Gotthard pass. His son, Henry, left Italy and came to London when he was about twelve. Whether or not it is true that he and his ultimate partner, and also Casella and Hicks, learnt the trade of thermometer making from Caesar Tagliabue, who, apparently also came from Como and established himself in Brooke Street, Holborn, in 1769, it is difficult to say. What is certainly true is that by 1840 he was established at 20 Greville St., Hatton Garden ; that by 1844 he was a junior partner of Mrs. Jane Pizzi at 19 Leather Lane, Hatton Garden, and that by 1845 he was established at the same address on his own account.

It is also certain that Joseph Warren Zambra, who was born in London in 1822, was by 1847 a junior partner of John Tagliabue, and that the Tagliabue family was very prominent in the instrument trade in its early days.

With the foundation of the firm of Negretti & Zambra in April 1850 success was immediately achieved. The original partnership, the deed of

which is still in existence, was for 10 years, 1850–60, but this was renewed in 1860 for a further 21 years, being unfortunately interrupted, however, by the death of Henry Negretti in 1879. Both families were represented continuously in the firm until 1935, when Mr. Mark Zambra retired, after which his family has not taken an active part. The family of Negretti still continues to be strongly represented. In 1946, after 96 years as a partnership and after becoming one of the largest private concerns in the country, the firm became a private company, and in 1948 a public company.

Just after its foundation the firm received considerable impetus from the Great Exhibition in Hyde Park in 1851 where a Prize Medal was awarded to them. The instruments shown at this Exhibition were : " Standard open cistern barometer, self-registering barometer, pocket sympiesometer, Rutherford's thermometer, Sixe's self-registering thermometer, hygrometers ". Negretti & Zambra were appointed Meteorological Instrument Makers to Queen Victoria and similar appointments followed from the Royal Observatory, Greenwich, and the British Meteorological Society (now the Royal Meteorological Society).

The association of Negretti & Zambra with the Meteorological Office began as soon as the Office was formed, instruments being purchased as early as 1858. In that year, for instance, twelve " Barometers for Fishermen " were bought and it is interesting to note that five of these are still in use and in good condition, namely at Lybster, Mousehole, Newhaven, Nairn and Filey. The early records of the Office also show purchases of a variety of other instruments from the firm.

In 1851 Negretti & Zambra patented a maximum registering thermometer which was a great improvement on existing types, and which is the type now in almost universal use for maximum and clinical thermometers. Negretti & Zambra made the aneroid barometer used by Glaisher in his balloon experiments, when, on September 5, 1862, he reached a height of seven miles.

During the hundred years of its existence the firm has occupied a large number of premises of which the most familiar, to the general public, was that at 38 Holborn Viaduct. These premises were destroyed by bombing on December 29, 1940. The Head Office is now at 122 Regent Street, the premises being acquired from John Newman, philosophical instrument maker in 1862.

Negretti & Zambra's production has not been confined only to meteorological instruments. Optical instruments were produced from 1909 until just after 1918 when it was decided to concentrate on the manufacture of industrial and aeronautical instruments. Boost and pressure gauges were then developed for the Air Ministry, and a patent mercury-in-steel transmitting thermometer was put on the market. This instrument is used in the form of a recorder for dry and wet bulbs by the Naval Weather Service, and at some of the land stations of the Meteorological Office. Pressure sensitive elements made by Negretti & Zambra are very widely used for the barometer units in radiosondes. In 1925 a department for the manufacture of electrical instruments was set up, and the firm continues to expand in many branches of instrument making.

Acknowledgments are due to the Editor *Instrument Practice* and to Negretti & Zambra, Ltd. for the loan of the blocks of the photographs facing p. 300, and for permission to make extracts from an article in the May issue of that publication, entitled " Negretti & Zambra—1850–1950 ".

USE OF THE HODOGRAPH IN ESTIMATING THE RAINFALL AT FRONTS

By J. M. CRADDOCK, M.A. and D. PRITCHARD

In a recent article by Parker[1]* a method is put forward for estimating the rainfall at warm and cold fronts, based on the argument that if the wind in the warm air relative to that in the frontal surface has a component towards the frontal surface, then upsliding must be taking place, whereas if the airflow in the warm air has a component away from the frontal surface, there must be downsliding. This method is also referred to by Penner[2], and must be fairly well known. Its theoretical basis depends on its being permissible to treat the frontal surface as a plane boundary moving without change of form, and is thus rather insecure, but it is nevertheless worth while to test the practical value of the method by trying it on a representative body of data in a straightforward and unsophisticated way. This has been done by applying it, as far as possible in the way suggested by Parker, to every eligible warm or cold front which passed Aldergrove during the two winter seasons, October 1947–March 1948 and October 1948–March 1949, and for which the observational data were available.

Warm front.—For the method to be applicable, the front must intersect the upper air sounding at a level which is not too near the surface and yet not too high. Hence the fronts considered were any which were between roughly 100 and 300 miles from Aldergrove at the time of the upper air sounding, and for each of these, 21 in all, the wind hodograph was drawn, using the data in the *Daily Weather Report*, and the direction of the surface front shown, as suggested by Parker. An attempt was made to identify the frontal transition zones by finding a zone in which the wind shear was parallel to the surface front, but was not very successful, as many of the hodographs had no such zone. Another criterion, that the frontal transition zone is a zone of relatively great wind shear and of wind veering with height separating zones above and below in which the shear is less, was effective in every case, although even here the upper or lower limit of the transition zone was uncertain in a few cases. The wind shear in the zone so defined was usually backed from a direction along the line of the surface front (with warm air on the right), the average value of the highly variable angle of backing being perhaps 20–30°. Further, the lower limit of this zone did not agree with, but generally lay above the upper limit of the cold air as found from the temperature soundings. The upper limit of the cold air, which is defined by Parker to be the level of the front, was used in all that follows, and was taken to be the most obvious kink on the temperature sounding below an inversion or zone of reduced lapse rate, without reference to cloud or humidity data. It is a level which cannot easily be identified from the hodograph alone, and which does not generally agree with the lower limit of the frontal zone as shown by the wind data.

Accepting as frontal level the upper limit of the cold air, the normal wind at that level (i.e. the component of the wind at that level normal to the surface direction of the front) is plotted in Fig. 1 against the actual speed of the front. This speed was found as accurately as possible in the way illustrated in Fig. 2, by plotting against time the displacements of the front between synoptic hours

* The index numbers refer to the list of references given on p. 292

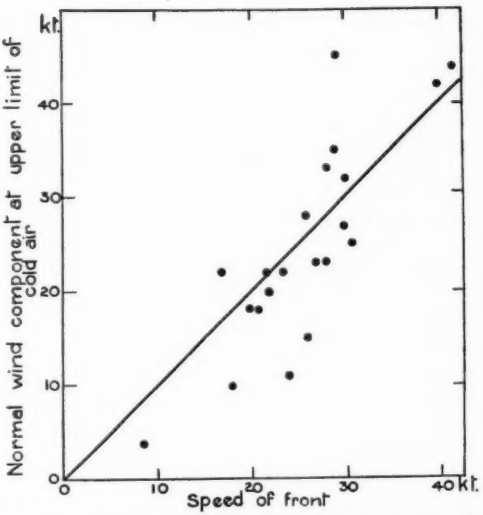


FIG. 1—SPEED OF WARM FRONT COMPARED WITH NORMAL WIND COMPONENT AT THE UPPER LIMIT OF THE COLD AIR

(the positions being taken from the 3-hourly working charts of the Central Forecasting Office, Dunstable) and finding the slope of the line of best fit, estimated by eye. Fig. 1 shows that there is in fact a strong association between the variables, the correlation being 0·78, and that there is no apparent tendency for the normal wind to be greater or less than the actual speed of the front. It seems, therefore, that the method used by Parker for estimating the speed of a warm front from an upper air sounding is a fairly good one. It is doubtful whether it is better than linear extrapolation when the position of the front has been fixed on several earlier charts, but should prove useful when earlier frontal positions are uncertain.

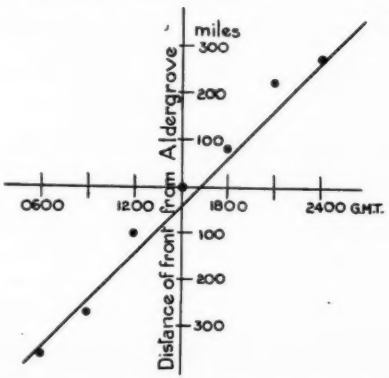
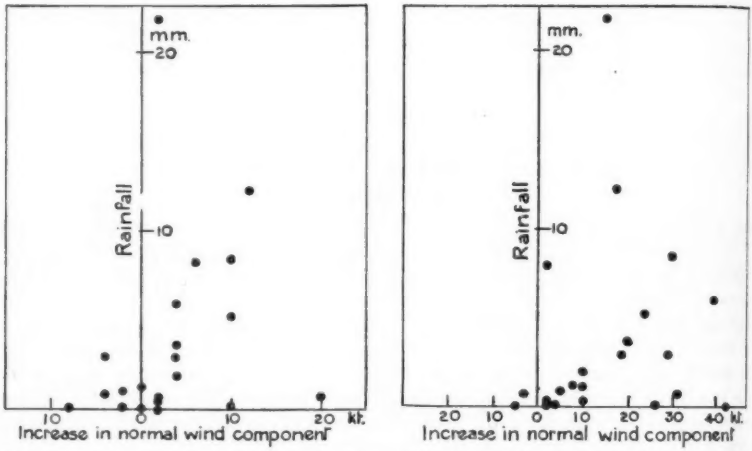


FIG. 2—ESTIMATION OF SPEED OF WARM FRONT
Distances were measured at each synoptic hour along the normal drawn from the position of the front at the time of the upper air sounding.

The increase or decrease of the normal wind above the frontal level is *prima facie* associated with vertical motion in the warm air, and provides the proposed estimate of the intensity of frontal rain. It is uncertain whether regard should be had to vertical motion only in the frontal zone, or to that in the warm air as well, so two measurements were made, of the increase or decrease of normal wind in the 100-mb. layer above the level taken for the front, and the increase for the whole layer from the front up to 400-mb. These values are plotted in Fig. 3 against the rainfall associated with the front, a mean value found from the hourly records of four stations in Northern Ireland (Aldergrove, Armagh, Ballykelly and Castle Archdale). Both these graphs show some association between the variables, and there is not much to choose between them. The correlation would not justify the use of the method for the numerical estimation of rainfall, but would support a qualitative statement, perhaps as follows : if the normal wind in the 100-mb. layer



(*a*) estimated by means of the shear in the normal wind component in the 100-mb. layer immediately above the upper limit of the cold air.

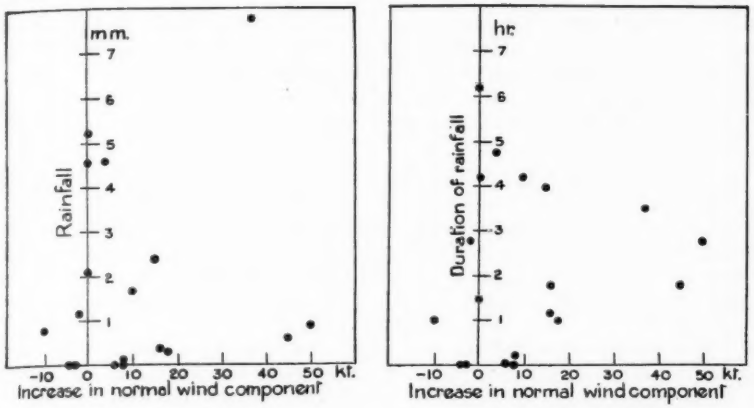
(*b*) estimated by means of the shear in the normal wind component in the layer between the upper limit of the cold air and the 400-mb. level.

FIG. 3—RELATION BETWEEN RAINFALL AMOUNT AND UPSLOPE MOTION AT THE WARM FRONT

above the front is decreasing with height, then little or no rain is to be expected (average amount about 1 mm.), but if the normal wind is increasing with height, considerable rain may fall (average amount about 5 mm.).

This association suggested that perhaps the intensity of rainfall depended on the intensity of the front as such, but a test, made using as measure of the intensity of the front the mean wind shear in the direction of the front from the frontal level up to 400-mb., did not reveal any association.

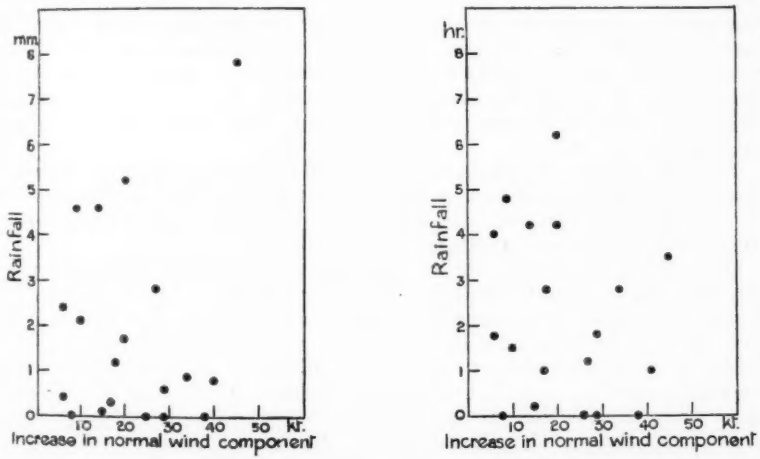
Cold front.—It is not possible to treat a cold front in quite the same way as a warm, because an upper air sounding which intersects the frontal surface will lie behind the front, and be available, generally, only after most of the frontal rain has already fallen. The estimate, to be of value, must be made before the front reaches the station concerned. So in this case the test was made, for the two winter seasons, on every upper air sounding at Aldergrove



(*a*) amount of rainfall. (*b*) duration of rainfall.

FIG. 4—RELATION BETWEEN RAINFALL AT COLD FRONTS AND THE INCREASE IN THE NORMAL WIND COMPONENT IN THE 500–300-MB. LAYER

which lay ahead of but within 200 miles of an approaching cold front. There were 19 of these, and the hodographs were drawn as before. These soundings lie wholly within the warm air, and there is no obvious argument for deciding on the layer in which the normal wind shear may be expected to represent the air flow up or down the frontal slope. Two alternatives were tried, the 500–300-mb. layer and the 950–400-mb. layer. The normal wind shear, which usually increased with height, is plotted against the amount and duration of frontal rain in Figs. 4 and 5. In none of these is there any noticeable association between the variables, so that the present evidence does not suggest that the method is of value for estimating the intensity or duration of rainfall at cold fronts.



(*a*) amount of rainfall. (*b*) duration of rainfall.

FIG. 5—RELATION BETWEEN RAINFALL AT COLD FRONTS AND THE INCREASE IN THE NORMAL WIND COMPONENT IN THE 950–400-MB. LAYER

[I was very interested to see the foregoing check of my method. However, as was pointed out in the original paper it is not possible to use the method to give an accurate quantitative estimate of actual rainfall since the stability of the warm air must also enter into the calculation, and it is not easy to allow for this quantitatively. The value of the method lies in its ability to indicate that rain will break out on a front which may not be giving rain at the time.

In the case of the cold front, I feel that the check was done in too unsophisticated a manner. Cold fronts fall into three definite classes : (i) those in which the normal wind decreases with height in the warm air above the frontal surface causing much cloud and rain behind the front ; (ii) those in which there is little change in normal wind with height, in this case the cloud occurs mainly in the warm air just ahead of the front and appears to be caused by a convective cell concentrated along the front ; and (iii) those in which there is a marked increase of normal wind with height and consequently results in no rain as a rule. It follows that the rainfall cannot depend on the normal wind except in cold fronts of type (i). I found that it is possible in practice to use the method to forecast outbreaks of rain behind cold fronts when the front was not previously giving any rain.—A. E. PARKER]

REFERENCES

1. PARKER, A. E. ; Relation between upper wind structure and rainfall at fronts. *Met. Mag., London*, **78**, 1949, p. 247.
2. PENNER, C. M. ; The use of upper winds in forecasting. *Weather, London*, **2**, 1947, p. 322.

ABLATION IN THE SCOTTISH HIGHLANDS

By D. L. CHAMPION
Assistant Director, Snow Survey of Britain

During the month of July 1949, the Durham University Exploration Society established a camp on the Ben Macdhui massif in the Cairngorms under the leadership of Mr. P. F. Green, from which the then extant snow-beds were surveyed and daily observations of the ablation were made on one of the larger beds. Standard thermometers and screen, etc., were set up near the camp, and these instruments were read at the fixed hours 0900, 1500 and 2100 G.M.T. each day.

The area covered by the survey included the mountains, Ben Macdhui, Braeriach, and Cairngorm, and extended as far south as the river Dee, to Beinn A' Bhuird in the east and Loch Einich in the west. Some 35 snow-beds were found of total area exceeding 320,000 sq. yd.

Fig. 1 shows the location of the snow-bed from which the observations of ablation were obtained, together with the site of the meteorological instruments set up near the camp above Coire Sputan Dearg. The extent of the snow-bed can be judged from Fig. 2, which shows one of the party walking across it. The ablation was measured by means of graduated poles which were hammered vertically into the snow, the fall in level being read off each day. It is assumed that the snow had well settled and any shrinkage of the mass during the period under observation has been ignored.

The period covered by the observations was from July 10 to July 27, a total of 18 days, and the observed ablation is shown in Fig. 3, together with the daily mean temperature. It will be seen that, as one would expect,

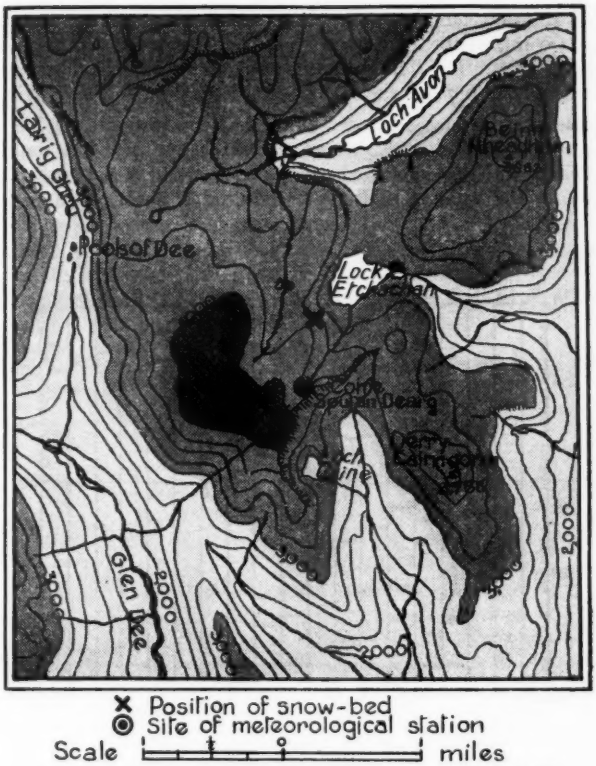


FIG. 1—POSITION OF SNOW-BED IN THE GRAMPIANS

The contour heights are given in feet.

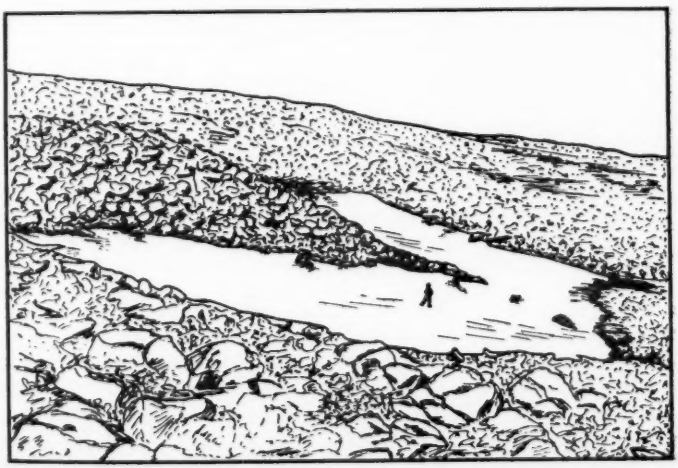


FIG. 2—EXTENT OF THE SNOW-BED

the rate of ablation tends to follow the mean temperature, the least daily ablation of 1·0 in. on the 19th coinciding with the lowest mean temperature of the period, i.e. 36°F. The greatest ablation occurred on the 22nd when the snow surface fell 6·7 in., the mean temperature on this day being 54°F.

The whole period was generally cloudy, with considerable hill fog, only the 10th, 21st, 24th and 27th having a mean cloudiness less than 7 oktas; and measurable rain was recorded every day except on the 10th, 17th, 23rd, 24th and 26th, the total rainfall for the period being 1·56 in.

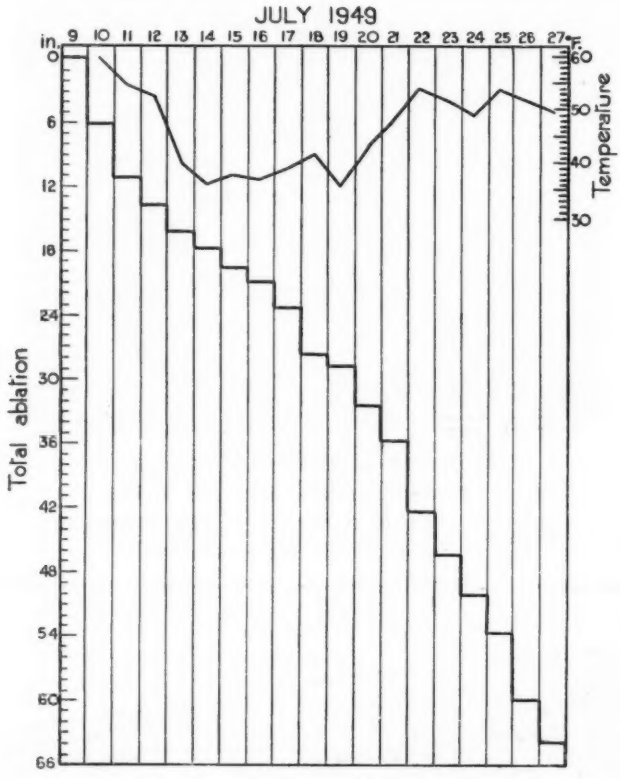


FIG. 3—COMPARISON OF MEAN DAILY TEMPERATURE AND DAILY ABLATION

The mean relative humidity was consequently high, only falling below 90 per cent. on the 10th, 12th and 19th. The total ablation during the period amounted to 63·9 in., and if this rate had been maintained it was assumed that the snow-bed would not have persisted throughout the summer.

In summer months by far the greatest factor in ablation is that due to the melting of the snow, and little can be due to direct evaporation from the surface of the snow-bed, particularly when the snow mass is frequently enveloped in cloud.

The relation between daily ablation and mean temperature above the freezing point is shown by the curve in Fig. 4, and can be roughly expressed as

$$A = 0{\cdot}24\ (t—32)$$

where A is the ablation in inches and t is the mean temperature in degrees Fahrenheit. It is of interest to note that the rate of ablation is 0·01 in. per degree per hour, and, assuming this rate was maintained at all the snow-beds examined, the total yield would be over 370,000 gallons of melt water per day. The importance of mountain snow-beds in assisting the flow of rivers used for irrigation, hydro-electric schemes, etc. during dry spells is well brought out by these results.

Further details of mountain snow cover in the British Isles will be found in the *Journal of Glaciology**.

Thanks are due to the British Glaciological Society for kind permission to publish the data.

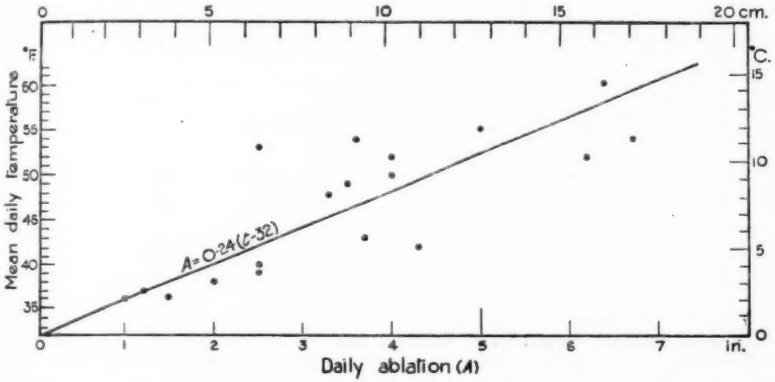


FIG. 4—RELATION BETWEEN DAILY TEMPERATURE AND DAILY ABLATION

VARIATION OF WIND WITH HEIGHT AT LOW LEVELS OVER THE SEA

By A. H. GORDON, M.S.

Introduction.—A brief analysis was undertaken of the variation of wind with height from data derived from pilot balloon ascents made from H.M. ships in Marsden Square 146 in the Atlantic Ocean west of the Bay of Biscay (40–50°N., 10–20°W.). The data covered the period 1937–44 inclusive. The analysis included only those ascents which were comparable level for level so that homogeneity of wind structure could be obtained. Thus the variation of wind between the surface and 2,000 ft. and between the surface and 4,000 ft. were treated separately using all available ascents which reached 2,000 ft. and 4,000 ft. respectively.

* HAWKE, E. L. and CHAMPION, D. L. ; Report on the snow survey of Great Britain for the season 1948–49. *J. Glaciol., London*, **1**, 1950, p. 362.

Mean scalar velocity.—Most of the observations of surface wind velocity in the analysis have been measured by anemometer although a few have been estimated from the state of the sea. The height of the anemometer above the surface of the sea may vary depending on the vessel from which the ascent was made but it is probably of the order of 100 ft. in most cases.

Table I shows the variation of mean scalar velocity with height together with the ratio of the mean velocity of the surface wind to the mean velocity of the wind at 2,000 ft. It is seen that the wind velocity increases a little between the surface and 1,000 ft. and then remains fairly constant. It would seem therefore that the wind at 2,000 ft. closely approximates to the gradient wind. The ratio (mean V_s)/(mean $V_{2,000}$) and mean of $V_s/V_{2,000}$ are higher than the normally accepted values of V_s/V_g. This may be partly due to the fact that the surface wind velocity is referred to about 100 ft. above the sea when it is measured by anemometer but to only 33 ft. when it is estimated. It may also be partly due to the fact that the ascents were limited to days of reasonable visibility when the height of the low cloud base was not below 2,000 ft.

TABLE I—VARIATION OF MEAN SCALAR VELOCITY WITH HEIGHT

	Surface—2,000 ft. 153 cases	Surface—4,000 ft. 81 cases
ft.	kt.	kt.
4,000	..	15·1
3,000	..	14·7
2,000	17·5	15·1
1,000	17·3	14·7
Surface	15·6	13·0
(Mean V_s)/(mean $V_{2,000}$)	0·89	0·86
Mean ($V_s/V_{2,000}$)	0·94	0·91

Ratio of surface to gradient wind at sea.—An analysis of 710 observations, taken at random, of the ratio of the wind at 50 ft. to the wind at 2,000 ft. made aboard ocean weather ships in the North Atlantic gave a mean value of 0·71. Other values of this order for the ratio of surface to gradient wind have been obtained by C. S. Durst[1]*, R. Frost[2] and other meteorologists[3,4].

Diurnal Variation of $V_s/V_{2,000}$.—Table II shows the diurnal variation of $V_s/V_{2,000}$ when the mean values are grouped at intervals between 0700 and 1900 local time. If the wind at 2,000 ft. can be considered to be inappreciably affected by any diurnal range it is seen that there is evidence

TABLE II—DIURNAL VARIATION OF $V_s/V_{2\,000}$ DURING DAYLIGHT HOURS

Local time ..	0700–0800	0900–1000	1100–1200	1300–1400	1500–1600	1700–1900
$V_s/V_{2,000}$ ..	0·92	0·99	1·01	0·97	0·82	0·82

of a diurnal range of surface wind velocity during daylight hours which reaches a maximum at or shortly before noon and a minimum in the mid afternoon and early evening.

* These numbers refer to the list of references on p. 297.

Mean vector wind.—Table III shows the variation of mean vector wind with height. In each case the wind at 1,000 ft. has veered from the surface wind and increased in velocity. Above 2,000 ft. the mean vector wind has backed and the velocity remained fairly constant.

TABLE III—VARIATION OF MEAN VECTOR WIND WITH HEIGHT

	Surface—2,000 ft. 153 cases				Surface—4,000 ft. 81 cases			
	Mean vector wind		Variation		Mean vector wind		Variation	
ft.	°	kt.	°	kt.	°	kt.	°	kt.
4,000 ..	..	..			328	5·3	back 9	−0·2
3,000 ..	..	..	..	..	327	5·5	back 6	+0.1
2,000 ..	327	4·9	back 1	+0·1	343	5·4	veer 4	+0·2
1,000 ..	328	4.8	veer 5	+0·9	339	5·2	veer 15	+0·8
Surface ..	323	3·9			324	4·4		

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2. FROST, R.; Atmospheric turbulence. *Quart. J. R. met. Soc., London*, **74**, 1948, p. 316.
3. SHAW, SIR NAPIER; Manual of meteorology. Vol. IV. Meterological calculus: pressure and wind. Cambridge, 1931.
4. GORDON, A. H.; The ratio between observed velocities of the wind at 50 feet and 2,000 feet over the North Atlantic Ocean. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 344.

OFFICIAL PUBLICATIONS

The following publications have recently been issued :—

Annual Report of the Director of the Meteorological Office presented by the Meteorological Committee to the Secretary of State for Air for the year April 1, 1949 to March 31, 1950.

This report contains an account of the work of the State Meteorological Service. Much of the work is directed towards meeting the day-to-day needs of the public, the Royal Air Force, the Merchant Navy, Civil Aviation, other Government Departments, and various industrial concerns and public utility services.

The pressing need for research is not overlooked, however, and the expansion of research into forecasting problems has been manifested during the past year by the establishment of the Napier Shaw Laboratory at Dunstable. At other establishments studies are being made of the physics of clouds and size of cloud droplets, using radar methods and aircraft equipped with instruments specially developed for the purpose. Other investigations include the sampling of air at great heights, turbulence at high levels, and the visibility of airport approach lights from the air. At the geophysical observatories, Kew, Eskdalemuir and Lerwick, records are maintained of the standard meteorological elements, radiation, terrestrial magnetism, atmospheric electricity, and seismic movements.

The increasing effort devoted to meteorological problems in agriculture is reflected by the introduction of a separate section in the Report describing activities in co-operation with the National Advisory Service of the Ministry of Agriculture and the special problems which are being studied for the benefit of agriculture. Another service instituted during the past year is a daily broadcast by television from London and Birmingham of meteorological charts and forecasts covering south-east England and the Midlands.

Assistance was given to the Meteorological Services of Ceylon and Persia by training members of the staff of those Services. Radio-sonde and radar-wind equipment was supplied to New Zealand, the Falkland Islands, and Hongkong.

The Report concludes with reference to international meetings of the International Meteorological Organization, the International Civil Aviation Organization, and the International Union of Geodesy and Geophysics, which were attended by senior members of the staff of the Meteorological Office.

METEOROLOGICAL REPORTS

No. 6—Equivalent Headwinds—application of upper wind statistics to air-route planning. By J. S. Sawyer, M.A.

The planning and operation of air routes through different climatic regions of the world requires a knowledge of the winds likely to occur on particular routes and their effect on the pay-load which can be carried by the aircraft. This report presents a method by which the available meteorological statistics regarding the free atmosphere may be adapted to provide the information required by the aircraft operator in a form in which he can use it.

The report gives the theoretical basis of the statistical treatment and also discusses the accuracy of the results. A comparison of the theoretical calculations with the practical results on two air routes is also given.

No. 7—Equivalent headwinds on some of the principal air routes of the world

This report gives the average equivalent headwind for a number of air routes of the world. An equivalent headwind is the difference between air speed and ground speed averaged throughout a flight. Separate values are given for each route for the four seasons and for every 10,000 ft. from 10,000 to 40,000 ft. The routes are for the most part those flown regularly by British aircraft.

Also given are figures for determining the headwind (greater than the average) which the aircraft must be able to meet in order to achieve a definite regularity of service. For example, on the route Karachi to Cairo at 40,000ft. in winter, the average equivalent headwind is 89 kt. If an 85 per cent. regularity of service is desired, the aircraft must be able to meet a headwind of 109 kt., and for 90 per cent. regularity, 113 kt.

The report should be of considerable use for long-term planning by regular air-route operators, by charter companies and by anyone planning to fly an aircraft overseas.

LETTER TO THE EDITOR

Rainbow without visible precipitation

At about 1935 G.M.T. on May 20, 1950, a rainbow was seen from Tunbridge Wells without visible precipitation. The sky was nearly covered with low fracto-cloud of indefinite type. The clouds in the north-west were strongly illuminated. Opposite there developed a strong primary bow with well marked colours and spurious bows of total width on the left of the arch as wide as the bow. There was a trace of a secondary bow. No rain was falling at the place of observation and there was no definite sign of virga from the clouds.

CICELY M. BOTLEY

2 Park Road, Tunbridge Wells, June 10, 1950

[Presumably the rainbow was formed in very fine droplets too small to be seen from the ground and which evaporated before reaching it. There was a feeble occlusion moving eastwards over south-east England on the evening of May 20, giving slight local rain.

Observations of rainbows without visible precipitation are scarce. Such a rainbow was seen by Mr. E. L. Hawke in 1934* with only cirrostratus cloud. A German observer, K. Glass† who kept a systematic watch for the phenomenon, saw it four times in five years. On three of the occasions reported by Glass the cloud state was similar to the one reported by Miss Botley and on the fourth there were 8 tenths of cirrostratus nebula above low fractostratus. —Ed. *M.M.*]

NOTES AND NEWS

Weather information from British whalers in the Antarctic

Merchant shipping has once more played a considerable part in aiding Antarctic exploration. The whaling fleets of several nations have supplied weather information, from the Antarctic Ocean, to the joint Norwegian-British-Swedish Expedition to Queen Maud Land. Amongst these fleets were ten vessels, owned by two British Whaling Companies, Messrs. Chr. Salvesen and Co., Ltd., and the United Whalers, Ltd. Recruited by the Marine Branch of the Meteorological Office, these vessels have, in co-operation with the Meteorological Bureau of South Africa, rendered assistance to the Expedition by voluntarily taking synoptic weather observations and transmitting their reports to "MET PRETORIA" for relay to the Expedition's base in the Antarctic mainland, during the 1949–50 whaling season.

Whaling is carried out on a highly competitive basis; and individual companies do not care to give away their position of operation to their competitors. Accordingly, Norsk Polarinstitutt (co-ordinating authority for the Joint Antarctic Expedition) prepared a separate cypher for each company, to be used in conjunction with the international weather code FM 21. The Meteorological Bureau of South Africa and the Expedition in the Antarctic were each in possession of all cyphers.

An event of historic meteorological interest resulted from this widespread scheme. Sufficient weather information was obtained from the Antarctic to issue daily during the whaling season, a special Antarctic inference for the benefit of the whalers. This inference was prepared and issued by the Naval Weather Service at Simonstown at the request of the South African Meteorological Bureau.

Slotted sunshine recorder

One of the difficulties experienced at stations lies in changing the sunshine card after sunset or before sunrise each day during summer when the sun does not set until a late hour. Private observers do not meet with this difficulty to the same extent as stations manned by staff who cease duty at the end of the normal working day, but even so it would often be an advantage to be able to change the card each day at some convenient hour before sunset.

The difficulty has now been overcome by the design of a sunshine recorder, similar in all respects to the Meteorological Office Mk.II instrument but with

* HAWKE, E. L.; A rainbow in cirro-stratus. *Met. Mag., London*, **69**, 1934, p. 65.
† GLASS, K.; Regenbogenbildung ohne Niederschlag. *Z. angew. Met.* (*Das Wetter*), *Leipzig*, **55**, 1938, p. 404.

slots, wide enough to take a sun card, cut through the summer-card section of the bowl at positions corresponding approximately to 0830 and 1530 L.A.T., when the card is in its normal position.

The method of working is as follows: at a convenient time of the day after 1530 L.A.T. (which may vary, in the British Isles, from about 4.20 p.m. to 5.10 p.m. B.S.T. according to the longitude of the observing station and the date) the card is withdrawn, from its normal position, in the direction in which the burn is progressing, until the "morning" end of the card just uncovers the slot cut through the afternoon section of the bowl at a position corresponding to approximately 1530 L.A.T.

To record the evening sunshine, the card is pushed back again so that most of the used portion passes through the slot to the back of the recorder bowl, the card being positioned correctly by placing a specified hour line on the card against a mark on the bowl.

At the same time a new card to receive the next morning's record is inserted in the normal groove at the other end of the bowl and allowed to project through the slot cut at about 0830 L.A.T. to the back of the bowl. This card is also positioned against a mark on the bowl.

Next day, at some convenient time before 0830 L.A.T. the card with the complete day's record on it is removed for measurement and the card with the morning record on it is withdrawn and replaced in the normal position in the recorder, care being taken to position it correctly against the mark on the bowl.

A clamping screw at each end of the groove prevents movement of the cards.

The Instruments Supply branch of the Meteorological Office now holds stocks of "slotted" sunshine recorders and is prepared to supply private stations, Health Resort stations and others which make reports to the Office under approved conditions. The cost of the recorders complete with a year's supply of cards is £30 9s. 5d., exclusive of the cost of a packing case and transportation. The cost of the case, however, would be credited in full, if returned carriage paid in good condition to the Meteorological Office, Headstone Drive, Harrow.

At present the slotted recorders are only available for use in the United Kingdom.

C. JOWETT

Loss of the French O.W.S. *Laplace*

It is with great sorrow that we record the tragic loss of the French O.W.S. *Laplace* which was blown up while at anchor in the Baie de la Fresnaie, near St. Malo, during the night of Friday, September 15, 1950. As a result of this explosion which is believed to have been due to a magnetic mine, 22 men were killed or drowned, 29 are missing, and 41 are known to have been rescued. The Captain of the *Laplace* is among the missing. Our readers will wish to join us in expressing our sympathy with the relatives of those who lost their lives.

The *Laplace* was a frigate of about 2,000 tons displacement and about 300 ft. in length, operated by the French Navy as an ocean weather ship in the North Atlantic, having been bought from the United States and specially fitted up in France for this work. Two other French ships of a similar type engaged on this duty are the *Mermoz* and *Le Brix*. The *Laplace* was one of a unique international fleet of vessels engaged upon humanitarian

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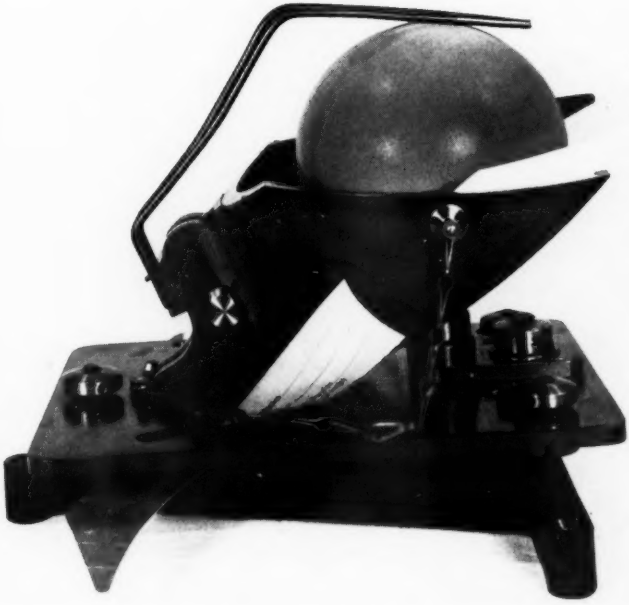
HENRY NEGRETTI
(See p. 286)

Reproduced by courtesy of "Instrument Practice"

JOSEPH WARREN ZAMBRA
(See p. 286)



SLOTTED SUNSHINE RECORDER

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FRENCH O.W.S. *Laplace*

and scientific work of considerable importance to all the countries bordering the North Atlantic. Her loss in peace time due to a relic of war time, besides involving French lives and French property, is a loss to international science.

The *Laplace* had only recently completed a period of 21 days duty at station KING, situated at position 45°N., 16°W. (in the Bay of Biscay). She was relieved at that station by the *Mermoz* on September 13. She had returned to Brest and was on her way to St. Malo to represent the French Navy at the opening of new harbour works. Being delayed by bad weather, her Captain decided to anchor in the Bay until daylight, rather than risk entering the harbour during dark hours. The disaster occurred about midnight when most of her crew were asleep, and the vessel sank within five minutes. These facts probably account for the large loss of life.

As an epitaph to an ocean weather ship, it is not perhaps unfitting to record her last coded synoptic message :—

SHIP K (FMMK) 140005/Z

SYNOP SHIP =
50452 15100 22822 97020 12616 22400 15300 05311 12945 =

FRENCH O.W.S. *Laplace*

Noctilucent clouds on the night of June 30-July 1, 1950

Noctilucent clouds were observed on the night of June 30, 1950 from Mildenhall, Suffolk, Wyton, Huntingdonshire (both lat. 52°20′N.), Pinner, Middlesex, (51°35′N.), Forest Hall, Northumberland (55°01′N.), and Workington, Cumberland (54°39′N.).

The Meteorological Office staff at Mildenhall saw the clouds from 2200 G.M.T. until midnight. They were within an irregular segment of a circle from 340° to 355°. The brightest patch was at an elevation of 5°. The colour was bluish-white with an occasional yellow tinge. Similar observations were made by the Wyton staff.

The clouds were observed from Pinner by Dr. Tor Bergeron, who had seen such clouds before from Sweden, and Mr. G. A. Bull at 2300 G.M.T. on a bearing of 350° and at an elevation of 3–4°. They were silvery-yellow below and bluish-white above. Mr. A. J. Acfield at Forest Hall and Mr. W. B. Housman at Workington saw two main streaks of bright blue-green light, half a degree in width and separated by half a degree stretching for 30° horizontally over the twilight glow 10° above the horizon and with bright blue-green cloudlets below. The display faded about midnight. No bright lines were seen in the spectroscope*.

Calculation from the elevations assuming a height of 60 miles, shows that the clouds were in latitude 58–59°N., that is they were over northern Scotland. Unfortunately the sky was too cloudy over Scotland for Mr. J. L. Paton's observing team (see *Meteorological Magazine*, December 1949, p. 354) to see them.

We are indebted to the Editor of *British Astronomical Association Circulars* for permission to include Mr. Acfield's and Mr. Housman's observations.

REVIEWS

Grundfragen der Wetterkunde. By Hellmut Berg. C. E. S. Bücherei, **31**. 7½ in. × 4½ in., pp. 172, *Illus*. Curt E. Schwab, Stuttgart, 1949. *D.M.* 4.80.

Prof. Berg's latest book appears in a series, " die C. E. S. Reihe ", corresponding to the British " Pelican " books. It gives a brief semi-popular

* For further details see *British Astronomical Association Circulars*.

description of a good deal of meteorology assuming very little mathematical or physical knowledge, in a very readable style.

There is an historical introduction. The major part of the book is divided into five parts :—

I. Physical bases. This part deals with the main elements, pressure, temperature, wind and their measurement.

II. Structure of the atmosphere, describing the temperature and chemical constitution of the atmosphere up to the ionosphere.

III. Clouds and precipitation, covering condensation processes, cloud classification and structure, artificial rain, and thunderstorms.

IV. Synoptic meteorology, with elementary dynamical meteorology, weather charts, air masses and fronts, solar effects on the weather, and the föhn.

V. Weather forecasting, a very brief sketch of methods of short, medium and long-range forecasting. The latter parts are concerned mainly with Baur's " stratospheric steering " ideas.

The best part of the book in the reviewer's opinion is Part III. Very recent researches, such as Seaton's estimations of ionospheric temperature and the American artificial precipitation trials of 1948, are mentioned in places. The book, however, as seems to be usual with this author's works, is rather unbalanced. A relatively great deal of space is devoted to such matters as the propagation of sound in the high atmosphere and the existence of free sodium there, but the pages on synoptic meteorology are concerned only with depressions and fronts and avoid anticyclones. Radiation is scarcely mentioned, and fog appears merely as a sub-class of clouds, " Outgoing-radiation clouds", with no description of the various ways in which it is formed or its prediction.

There are fourteen excellent cloud photographs at the end of the book. The diagrams of Figs. 47 and 49 are interchanged.

G. A. BULL

Weather Lore. By Richard Inwards. Revised by E. L. Hawke. $8\frac{1}{2}$ in. $\times 5\frac{1}{2}$ in. pp. 252. *Illus.* 4th edition. Published for the Royal Meteorological Society by Rider and Company, London, 1950. 12*s.* 0*d.*

The third edition of Richard Inwards' collection of proverbs, sayings and rules concerning the weather was published in 1898. It has long been out of print and had become an expensive rarity on second-hand book shelves. The fourth edition is therefore certain of its welcome. It will make a treasured addition to the home libraries of meteorologists and antiquarians, and contains much to take and hold the attention of the general reader.

Richard Inwards, a former president of the Royal Meteorological Society, died in 1937 and bequeathed to the Society the copyright of "Weather Lore". The Council of the Royal Meteorological Society invited Mr. E. L. Hawke, M.A., F.R.A.S., a vice-president of the Society, to prepare this fourth edition for publication during the Society's centenary year—an action which would certainly have met with the approval of the author who had for so many years been the father of the Society.

Such a compendium as Richard Inwards' required little revision on the part of the present editor. He has aimed at inserting occasional annotations where he thought present-day knowledge would add to the interest. These annotations are sometimes open to contention but are full of general interest. The modern meteorologist will, however, be disappointed to find that no effort has been made to link at least a few of the sayings with synoptic situations,

and will no doubt regret that this opportunity has been missed. Weather forecasting has undergone three fairly well defined phases. The first was built on experience—an era of weather signs, a linking of optical phenomena and winds with ensuing weather. The second was an instrument era founded on the work of Robert Hooke. This was the period of barometers and thermometers, a period which has added its own quota to the store of weather sayings and which the present edition does well to incorporate. The third is the era dependent upon rapid communications—the synoptic era. It would have been stimulating to all to have seen the lessons learnt from the last phase applied to the findings of the earlier phases, and to have seen those predictions for these islands extending beyond periods of two or three days firmly contradicted.

A small number of sayings which Inwards probably inserted in order to preserve them, but which contain no reference to the weather, have been omitted. These are far outnumbered by the additions which include Buchan's cold and warm periods and some Welsh weather lore.

The reviewer was surprised to find the popular saying

Rain before seven
Fine before eleven

divorced from the final couplet :—

Rain after two
Rain the day through.

Both couplets form part of the whole in the lore of the Welsh border country. He was also surprised to discover the Welsh weather lore now included to be completely foreign to him.

Other changes include the omission of those tables of dubious accuracy listing plants which should bloom on certain saints' days ; the addition of a few supplementary items found in Inwards' handwriting on one of his own copies of an earlier edition ; and an excellent preface and a biographical note on Richard Inwards by the present editor.

The volume as it stands is probably the finest of its nature, representing as it does in essence the observations, deductions, and experiences of farmers, sailors, naturalists and all men who through the ages have been subjected to the vagaries of a " temperate " climate. Like the earlier edition it contains an excellent bibliography and subject index. It is attractively bound and the Royal Meteorological Society and the editor are to be congratulated on their work.

G. J. EVANS

OBITUARIES

H. N. Warren, O.B.E.—By the death of Mr. Warren, Director of the Australian State Meteorological Service, meteorologists the world over, and particularly those in the British Commonwealth of Nations, have lost an able and loyal colleague.

Herbert Norman Warren was born at Melbourne on April 6, 1888, and was educated at the University of Melbourne. In 1914 he joined the Public Service and entered the Department of Home Affairs of Victoria. During the first world war he served as a Company Commander with the Australian Forces, having previously served with the Victoria Scottish Regiment from 1906 to 1908. After the war he returned to the Public Service, in which he held a number of appointments, the most important being that on the Board

for the organization of Australian Commonwealth Departments. The experience which he there gained was to stand him in good stead when he was attached to the Meteorological Branch in 1938 to organize it for aviation and defence. In 1939 he was made Assistant Director (Administration), and the following year he became Director.

During the second world war he played an active part in connexion with the Allied operations in the south-west Pacific. He was Director of the Allied Meteorological Services in that Theatre and held a staff appointment at Allied Air Force Headquarters. He attended conferences at Batavia, Singapore and Auckland, and became Chairman of the Meteorological Committee set up at G.H.Q., South-west Pacific Area, in 1943. He held the rank of Group Captain in the Royal Australian Air Force, and was awarded the O.B.E. for his services.

Since the end of the war Mr. Warren continued to play an active part in international meteorology. He attended the Conference of Directors held in London in February 1946, and was a prominent figure at the Conference of Empire Meteorologists which immediately followed. As President of Regional Commission V of the International Meteorological Organization he took the lead in standardizing meteorological procedures in the South-west Pacific Region. He was present at the meetings of the International Meteorological Organization Commissions at Toronto in 1947 and at the Conference of Directors which followed in Washington. At the latter meeting he played an important and effective part as chairman of the committee responsible for drafting the Convention for the new World Meteorological Organization. The last task that he performed was to attend the meeting of the Executive Council of the International Meteorological Organization at Lausanne in May of this year, and it was during the course of this meeting that he was taken seriously ill. After resting for a while in a local clinic, he came back to England at the end of June, and almost immediately left by boat for home. He was destined, however, not to reach Melbourne, but died on the ship at Adelaide on August 5.

Those who had the good fortune to know Mr. Warren recognized in him a man of strong character and robust common sense. His independence of thought made him the champion of any cause which he regarded as worthy of support, and his sense of fairness earned for him the respect of all. Those of us who met Mrs. Warren at Toronto or in this country in 1947 will wish to offer her our profoundest sympathy in her loss.

N. K. JOHNSON

Mr. Arthur Burnet.—Many readers will learn with regret of the death of Mr. Arthur Burnet who, in 1942, at the age of 63, joined the staff of the Meteorological Office in order to take a share in the war effort. After working on the harmonic analysis of pressure as part of an experiment in long-range forecasting, he joined the newly formed Upper Air Section and worked at Stonehouse and Harrow until his resignation in October 1946. Up to a few months ago he was a familiar figure at scientific meetings.

METEOROLOGICAL OFFICE NEWS

Ozone observations.—In 1947, at the instigation of the Gassiot Committee of the Royal Society, plans were made to resume regular observations of atmospheric ozone at a network of stations in the United Kingdom. To this end, modern ozone spectrophotometers of the Dobson type have recently been

supplied to the upper air units at Camborne and Downham Market, while Aldergrove and Lerwick are to be similarly equipped later. Ozone measurements are to be made normally twice a day, near to the time of routine radiosonde ascents.

This project is part of a wider scheme, sponsored by the International Meteorological Association, to obtain ozone measurements by a standard procedure at a number of stations in Europe and neighbouring areas so that the distribution and variation of ozone, which reaches maximum concentration between heights of 20 and 30 Km., may be investigated in relation to the meteorological situation. The upper air information now available, which is more abundant and more reliable than before the war, should facilitate these researches.

Examination successes.—We offer congratulations to the following on their recent successes :

(1) Mr. R. J. Ogden and Mr. P. M. Shaw, who have obtained the B.Sc. (Special) degree of London University in mathematics with second class honours.

(2) J. P. Barry, G. F. W. Clapp, Miss S. Daniels, J. E. Evans, J. O. Friend, C. H. Jarvis, J. S. Job, A. H. Norton, P. K. O'Shaughnessy, H. L. Rigden, S. M. Ross, Miss E. E. Smith, F. J. Smith, R. C. A. Sutherland and A. C. Wall, who have passed the Intermediate B.Sc. examination of London University.

Bishop Shield Competition.—The 1949–50 competition for the Bishop Shield ended with the Air Ministry Annual Sports held at the Polytechnic Stadium, Chiswick, on Wednesday, August 30. The Meteorological Office retained the Shield with a record total of 125 points and also won the Jones Memorial Cup for scoring more points at the Sports than any other division.

One of the most pleasing features of the success of the Office on Sports Day was that so many individuals contributed to it. Nearly one third of the competitors represented the Office and they gained points in all but a few events. For the first time in the competition our team won the tug-of-war, just beating the Directorate of Accounts' side in the final after a long and exhausting contest. In the relay races our ladies' team gained a great victory and the men's team ran well to come in second.

The close of one competition for the Bishop Shield is the signal for the next year's competition to begin and two days after the athletic sports our swimmers gave us a good start for 1950–51. We thank and congratulate all who have done so well in the past, and ask them and other enthusiasts to put forward their best efforts for the coming season and thus ensure a "hat-trick" for the Office in the competition for the Shield.

Retirement—Mr. H. E. Carter, who retired on August 31, 1950, within a few days of his 64th birthday, joined the Meteorological Office in October 1901 when it was housed at 63 Victoria Street. In 1907 he transferred to the British Rainfall Organization under Dr. H. R. Mill and after service in the first world war rejoined the Office, which by that time had taken over the British Rainfall Organization. After service at Lympne and in the Middle East, Mr. Carter was posted in 1936 to the Branch Office at Edinburgh, and in 1946 returned to work on British Rainfall in the British Climatology Branch at Harrow. His chief interest has been rainfall and his keenness for accuracy and gift for spotting errors will long be remembered by those

who have worked with him. Good wishes for a long, active and pleasant retirement go with him.

Staff losses.—Four members of the staff of the Meteorological Office were recently transferred to posts in the Executive Class in the Air Ministry. They are: Miss A. W. C. Fitch, who had been in the Office since 1917, the last ten years of which were spent in charge of a section of the Marine Branch; Mr. W. Peniston-Bird, who joined the Office in 1921, and had been in charge of the office at Felixstowe for three years before his transfer; Mr. G. R. Read and Mr. L. Campbell, who had served in the Office since 1934 and 1938 respectively.

We wish these officers every success in their new sphere of work.

The Meteorological Office in Iraq is losing the valuable services of Mr. E. Haren Cohen, Senior Observer. Mr. Cohen first joined the Meteorological Service of Iraq in 1928 while it was under the control of the Royal Air Force. When the service was transferred in 1931 to the Meteorological Office he remained to train locally entered observers to take over the work from airmen. His resignation now is due solely to the necessity for the transfer of his family to Israel.

To the many officers who have served in Iraq since 1928, Mr. Cohen's loyalty, careful work and experience in local matters were of great value and they will wish him well in his new life. A letter of farewell has been received from Mr. Cohen, in which he asks that his good wishes may be conveyed to all staff of the Meteorological Office.

WEATHER OF AUGUST 1950

Mean pressure was above 1020 mb. over the Azores and westward of the Azores nearly to Bermuda, and slightly below 1000 mb. over a small area south of Iceland, centred in about 60°N., 20°W. The mean was below 1005 mb. over part of the Sahara slightly north of the tropics, and below 1010 mb. over southern California and Arizona. Pressure was below the normal for August from the southern shore of the Baltic southwards to the Sahara, over western Europe, the Azores, Iceland, and the Atlantic between southern Greenland and the Azores. The deficit was rather more than 10 mb. southward of Iceland between about latitudes 54°N. and 60°N., but was generally small. Pressure was above normal from the Baltic and the extreme north-west of Russia north-westwards to northern Greenland and Spitsbergen, the excess being about 6 mb. in Finland. Over North America deviations from the normal were small.

In the British Isles the weather of August was generally unsettled and wet on the whole, with frequent thunderstorms. It was very wet in western districts of England and Wales, particularly in the south-west. There were no really hot days, the warmest occurring from about the 4th to the 8th and the 20th to the 22nd, but minimum temperatures were often high. It was sunny in the north and east of Scotland,

During the opening days of the month a shallow depression off the west of Scotland moved east to Denmark causing showers and rather widespread thunderstorms, though there were long bright periods in many places. On the 4th a new depression south-west of Iceland moved slowly east-north-east and associated troughs moved north-east giving rain in the west and north on the 4th and 5th and slight local rain on the 6th. Meanwhile a small anticyclone over north-west France moved north-east and became absorbed in

a large anticyclone centred over north Russia. Temperature rose and the period 4th to 8th was warm; day temperature reached 81°F. in London and 80°F. at Mildenhall on the 6th, 80°F. at London Airport on the 7th and 80°F. at Mildenhall on the 8th. On the 7th and 8th a depression moved from mid Atlantic north-east to westward of Scotland and then turned north, while troughs of low pressure crossed the British Isles giving thunderstorms in eastern districts on the 7th and heavy rain in some parts on the 8th (2·16 in. at Filindre, near Cowbridge, Glamorgan). On the 11th and 12th small secondary disturbances to a depression south of Iceland moved north-east across the country causing rain in the north and west on the 11th and more general rain on the 12th (3·27 in. at Blaenau Festiniog, Merioneth, and 2·11 in. at Rhondda Water Works, Glamorgan on the 11th). On the 14th a wedge moved east over England and mainly fair weather prevailed in the south and east but more rain occurred in the west and north. On the 15th a depression developed off north-west Scotland and moved north and later turned west. Meanwhile associated secondary depressions or troughs moved irregularly north over the British Isles; rain, heavy in places, fell on the 15th (2·70 in. at Blaenau Festiniog) and in the following days rather cool weather prevailed, with frequent showers and fairly widespread thunderstorms. By the 20th pressure was high over Germany and low north-westward of Ireland, while a new depression developed in mid Atlantic and moved quickly east to the west of Ireland where it remained almost stationary until the 23rd. Temperature rose again reaching 78°F. at London Airport and Guernsey on the 21st and 80°F. at Mildenhall and London Airport on the 22nd. Shallow troughs moved over the British Isles giving heavy rain locally particularly in the south-west and in Lancashire on the 20th (1·90 in. at Wigan Water Works, Worthington, Lancashire), and local thunder in eastern districts on the 21st. On the 22nd and 23rd cold fronts moving east across the country caused showers and widespread thunderstorms, with heavy rain locally. Thereafter, on the 24th a shallow secondary depression off our south-west coasts moved north-north-east and on the 25th and 26th another shallow secondary off south-west Ireland moved north; rain and thunderstorms occurred, the latter being widespread on the 24th, but there were also sunny periods. Again, on the 27th and 28th, a trough of low pressure west of Ireland moved slowly south-east giving showers, rather widespread thunderstorms, and heavy local rain. Subsequently troughs to a shallow disturbance off north-west Ireland moving across England caused further thundery rains, which were heavy locally on the 30th, 2·09 in. being registered at Guernsey. Thunderstorms in south-east England on the 31st were associated with a shallow depression over northern France.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	83	40	+0·3	147	+3	99
Scotland	74	31	+1·0	115	+2	116
Northern Ireland ..	72	39	−0·2	135	+5	95

RAINFALL OF AUGUST 1950
Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	2·56	116	*Glam.*	Cardiff, Penylan ..	8·68	207
Kent	Folkestone, Cherry Gdn.	2·63	110	*Pemb.*	St. Ann's Head	6·59	196
,,	Edenbridge, Falconhurst	3·38	129	*Card.*	Aberystwyth	8·21	214
Sussex	Compton, Compton Ho.	3·92	127	*Radnor*	Tyrmynydd	8·17	153
,,	Worthing, Beach Ho. Pk.	2·43	108	*Mont.*	Lake Vyrnwy	8·48	156
Hants	Ventnor, Roy. Nat. Hos.	2·80	141	*Mer.*	Blaenau Festiniog ..	20·00	178
,,	Bournemouth	2·00	79	*Carn.*	Llandudno	3·97	144
,,	Sherborne St. John ..	3·82	158	*Angl.*	Llanerchymedd	6·34	175
Herts.	Royston, Therfield Rec.	3·78	147	*I. Man*	Douglas, Borough Cem.	7·21	166
Bucks.	Slough, Upton	3·43	158	*Wigtown*	Port William, Monreith	6·23	165
Oxford	Oxford, Radcliffe ..	3·05	134	*Dumf.*	Dumfries, Crichton R.I.	6·32	156
N'hant.	Wellingboro', Swanspool	1·70	71	,,	Eskdalemuir Obsy. ..	8·12	166
Essex	Shoeburyness	1·63	92	*Roxb.*	Kelso, Floors	3·04	107
,,	Dovercourt	1·72	96	*Peebles*	Stobo Castle	3·75	109
Suffolk	Lowestoft Sec. School ..	1·58	72	*Berwick*	Marchmont House ..	2·72	88
,,	Bury St. Ed., Westley H.	1·72	66	*E. Loth.*	North Berwick Res. ..	2·23	74
Norfolk	Sandringham Ho. Gdns.	4·64	172	*Midl'n*	Edinburgh, Blackf'd. H.	2·32	74
Wilts	Bishops Cannings ..	2·66	86	*Lanark*	Hamilton W. W., T'nhill	5·29	155
Dorset	Creech Grange	3·50	122	*Ayr*	Colmonell, Knockdolian	5·01	135
,,	Beaminster, East St. ..	5·54	177	,,	Glen Afton, Ayr San. ..	5·37	99
Devon	Teignmouth, Den Gdns.	3·29	146	*Bute*	Rothsay, Ardencraig ..	5·61	115
,,	Cullompton	5·74	188	*Argyll*	L. Sunart, Glenborrodale	..	..
,,	Ilfracombe	7·89	220	,,	Poltalloch	6·82	190
,,	Okehampton, Uplands ..	7·62	180	,,	Inveraray Castle ..	7·63	180
Cornwall	Bude, School House ..	6·13	217	,,	Islay, Eallabus	5·95	196
,,	Penzance, Morrab Gdns.	6·71	212	,,	Tiree	4·88	168
,,	St. Austell	7·26	201	*Kinross*	Loch Leven Sluice ..	4·19	166
,,	Scilly, Tresco Abbey ..	4·32	157	*Fife*	Leuchars Airfield ..	2·45	82
Glos.	Cirencester	4·75	158	*Perth*	Loch Dhu	9·24	177
Salop.	Church Stretton	3·58	107	,,	Crieff, Strathearn Hyd.	7·03	167
,,	Cheswardine Hall ..	7·00	211	,,	Pitlochry, Fincastle ..	5·11	144
Worcs.	Malvern, Free Library ..	3·62	125	*Angus*	Montrose, Sunnyside ..	3·13	113
Warwick	Birmingham, Edgbaston	3·21	118	*Aberd.*	Braemar	3·58	105
Leics.	Thornton Reservoir ..	2·59	93	,,	Dyce, Craibstone ..	3·18	105
Lincs.	Boston, Skirbeck	1·82	76	,,	Fyvie Castle	2·60	82
,,	Skegness, Marine Gdns.	2·78	114	*Moray*	Gordon Castle	1·92	61
Notts.	Mansfield, Carr Bank ..	3·71	133	*Nairn*	Nairn, Achareidh ..	1·98	63
Derby	Buxton, Terrace Slopes ..	4·80	110	*Inverness*	Loch Ness, Garthbeg ..	3·45	108
Ches.	Bidston Observatory ..	5·57	181	,,	Glenquoich	8·53	104
Lancs.	Manchester, Whit. Park	..	..	,,	Fort William, Teviot ..	7·67	153
,,	Stonyhurst College ..	8·90	176	,,	Skye, Duntuilm	5·66	127
,,	Squires Gate	6·60	193	*R. and C.*	Tain, Tarlogie House ..	2·20	61
Yorks.	Wakefield, Clarence Pk.	3·71	143	,,	Inverbroom, Glackour ..	4·54	109
,,	Hull, Pearson Park ..	4·48	154	,,	Applecross Gardens ..	6·38	135
,,	Felixkirk, Mt. St. John ..	4·50	158	,,	Achnashellach	6·11	110
,,	York Museum	4·86	193	,,	Stornoway Airfield ..	3·54	96
,,	Scarborough	3·82	138	*Suth.*	Loch More, Achfary ..	6·32	108
,,	Middlesbrough	4·66	170	*Caith.*	Wick Airfield	3·44	125
,,	Baldersdale, Hury Res. ..	5·86	168	*Shetland*	Lerwick Observatory ..	4·37	145
Norl'd.	Newcastle, Leazes Pk. ..	5·32	189	*Ferm.*	Crom Castle	5·94	143
,,	Bellingham, High Green	4·32	122	*Armagh*	Armagh Observatory ..	5·30	140
,,	Lilburn Tower Gdns. ..	2·62	93	*Down*	Seaforde	5·68	151
Cumb.	Geltsdale	6·82	165	*Antrim*	Aldergrove Airfield ..	4·02	113
,,	Keswick, High Hill ..	8·06	154	,,	Ballymena, Harryville ..	6·37	149
,,	Ravenglass, The Grove ..	6·28	138	*L'derry*	Garvagh, Moneydig ..	5·28	135
Mon.	Abergavenny, Larchfield	5·50	185	,,	Londonderry, Creggan ..	4·61	99
Glam.	Ystalyfera, Wern House	13·46	218	*Tyrone*	Omagh, Edenfel ..	6·16	144